Science Lab Teacher's Guide: Air Quality

Standards

This science lab is designed for high school or advanced middle school students. It may be used to support national science education standards NS 9-12.6, personal and social perspectives. The lab will help students should develop understanding of

- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Because the lab is designed to be used nationally and not all school districts use the same lesson plan format, the lessons are formatted according to the commonly-used constructivist model of learning called the ”Five Es." Each E describes a process that the students undergo rather than what the teacher does: Engage, Explore, Explain, Extend, and Evaluate. The students build their knowledge and skills from what they already know and can do. First, the students Engage in the lesson by being exposed to information that is meaningful to them and excites them to learn more. They then Explore more about the topic by participating in teacher-led and student-directed activities. The students are then asked to Explain what they have learned to solidify their new understanding of the concepts. The students then elaborate or Extend their learning by applying what they have learned to new situations, to broaden their perspective and deepen their understanding. Last, they are asked to assess their own learning and allow the teacher to Evaluate their performance.

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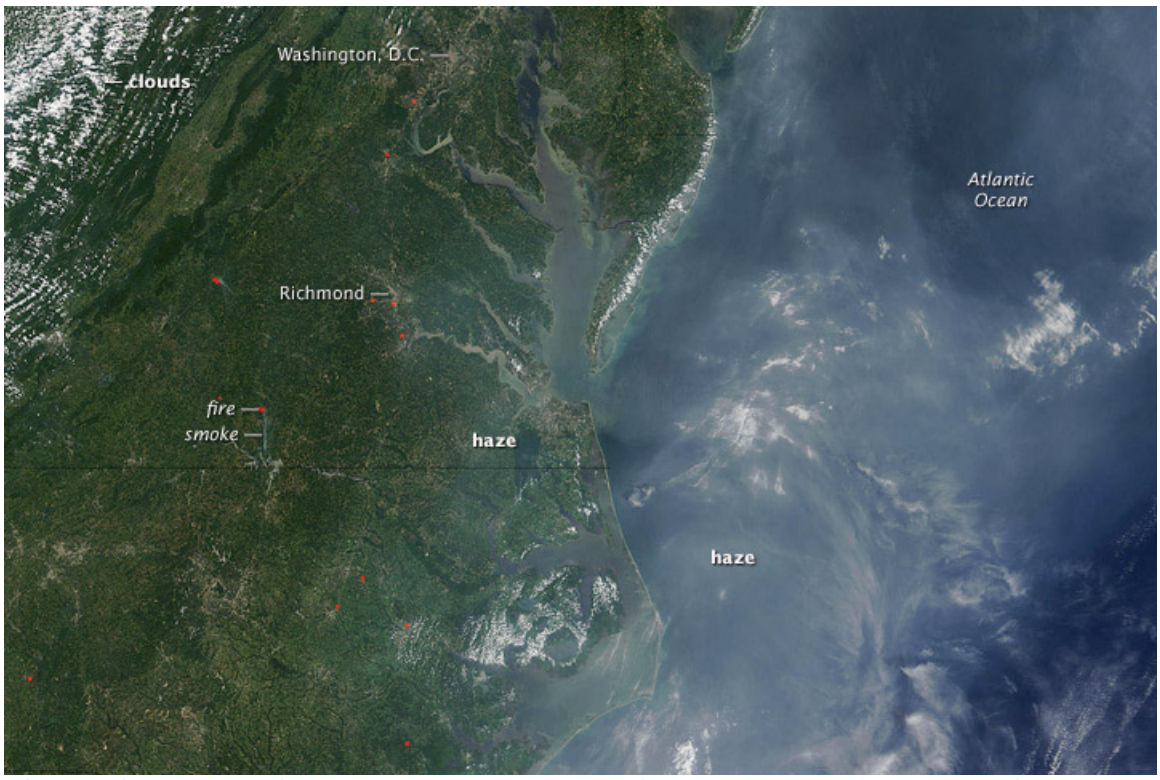
Teacher Background Information

July 25, 2005, was a scorcher. From the Midwest to the Eastern Seaboard of the United States, people cranked up the air conditioner as temperatures soared over a hundred degrees in another of a line of hot days. Those brave enough to venture into the heat found the air thick with haze. The heat turned emissions from cars and power plants into a soupy haze of ground-level ozone and fine particles left over from burning fossil fuels. Trapped in place by the high pressure system that had settled over the eastern and central United States, the haze had built up over several days. In many places, the Environmental Protection Agency warned that the air was unhealthy to breathe for those sensitive to poor air quality such as children, older adults, or people with heart disease, asthma, and other respiratory ailments.



The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this photo-like image of haze in the Eastern United States on July 26, 2005. Easier to see over the ocean, gray-tan haze hangs over the Mid-Atlantic region. Fires are marked with red dots. The image illustrates that haze is not uniform. Image courtesy Earth Observatory.

But air quality was not the same everywhere. Pollution can build up in isolated pockets, and local sources (an industrial plant or a busy road) can add to the overall poor air quality. This lab helps students compare air quality at their location with other locations through simple observations and analysis of measurements from EPA ground stations and NASA satellite data.

Pollution and health

Air is essential to life. Poor air quality threatens the health of all living things from humans to plants. There are many types of air pollution, and each have a different effect on human health. The two most common types of air pollution in the United States are ozone and particle pollution. Both irritate the respiratory system, making it difficult to breathe, but can also have a more serious impact on health.

Ozone is a colorless gas that forms when emissions from cars, power plants, and industry react with sunlight. Ozone is a major component in urban smog. Ozone pollution irritates the respiratory system, causing coughing and throat irritation, makes

breathing difficult, aggravates asthma, and can inflame and damage the lining of the lungs over time.

Particle Pollution is any kind of particle or liquid droplet in the atmosphere. Particle pollution, or aerosols, has many sources. Fine particles, small enough to get into the lungs, primarily come from combustion in cars, power plants, fires, and industry. Coarse particles tend to have natural sources such as dust or sea salt. Particle pollution may aggravate heart and lung disease. The number of hospital visits associated with lung and heart disease goes up when particle pollution is high. Particle pollution is associated with heart attacks and cardiac arrhythmias, causes difficulty breathing, and makes people more susceptible to respiratory infections.

Since air quality can have such a big impact on health, the U.S. Environmental Protection Agency issues color-coded air quality updates to alert people when pollution levels are high enough to be harmful. Many communities have established action plans to limit the impact of poor air quality on bad days.

The EPA's air quality index was designed to be an easy way to help people quickly relate current air quality to health risks.

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201-300	Health alert: everyone may experience more serious health effects.
Hazardous	> 300	Health warnings of emergency conditions. The entire population is more likely to be affected.

How is air pollution monitored?

The EPA alerts are based on both forecasts made with models and current observations. More than 4,000 monitoring stations track six different types of air pollution, including ozone and particle pollution, across the United States. The stations record hourly data, as well as daily maximum and minimum measurements.

These stations report what air pollutions levels were, but to provide warnings, the EPA has to make a forecast. Just as a weather forecaster uses a computer model to predict what the weather will be, forecasters at the EPA and state and local air quality offices use computer models to predict air quality. Models can show how pollutants will build in the atmosphere given the weather conditions and can predict where air pollution will travel. Models are necessary in predicting air quality because conditions change from day to day.

Air quality fluctuates from day to day for a number of reasons. Most obviously, air quality changes if more pollutants are put into the atmosphere. A large event such as a dust storm, wildfire, or volcanic eruption can dramatically darken the skies. Emissions also climb when energy demand goes up as it does on hot days. Scientists have also noted a weekly cycle in emissions dependent on local culture. In the United States, for example, air quality tends to be better on Saturdays and Sundays when fewer cars are on the road and electricity demand is lower because fewer businesses are operating.

Second, concentrations of pollutants in the atmosphere depend on the weather. Since sunlight is a necessary ingredient in ozone formation, ozone pollution levels tend to be highest during long summer days. A weather inversion, when warm air is trapped beneath a layer of cooler air, also leads to poor air quality since surface air has nowhere to go. Pollutants build in the pocket of trapped air. Inversions are especially common in cities surrounded by mountains such as Mexico City, Los Angeles, or Salt Lake City.

Finally, air pollution can have a local source, such as a power plant or factory, or it can come from somewhere else. Smoke from western wildfires can impact air quality in the Eastern United States. Dust from Africa clouds Florida's skies, and haze from Asia can reach the U.S. West Coast. Satellites have been instrumental in tracking pollution as it travels from place to place around the globe.

Why monitor air quality at your school?

Air pollution levels for your region are recorded at state monitoring stations, but air pollution does not necessarily spread itself evenly throughout the region. You may live next to a busy highway or some other source of pollution, or the topography of the land or city may concentrate pockets of polluted air near you. To know exactly what is in the air you are breathing, you need to monitor the air where you are.

Additional Resources

Feature Articles about Air Quality:

- Allen, J. (2002, January 27). Chemistry in the Sunlight. Earth Observatory. http://earthobservatory.nasa.gov/Features/ChemistrySunlight/
- Allen, J. (2002, April 19). The Ozone We Breathe Earth Observatory. http://earthobservatory.nasa.gov/Features/OzoneWeBreathe/

- Beitler, J. (2006, October 17). Tracking Nature's Contribution to Pollution. Earth Observatory. http://earthobservatory.nasa.gov/Features/ContributionPollution/
- Hays, Jeffrey. (2010, April). Facts and Details: Air Pollution in China. http://factsanddetails.com/china.php?itemid=392&catid=10&subcatid=66Materials
- Lindsey, R. (2004, August 17). A New IDEA in Air Quality Monitoring. Earth Observatory. http://earthobservatory.nasa.gov/Features/IDEA/
- Lindsey, R. (2004, January 5). Smoke's Surprising Secret. Earth Observatory. http://earthobservatory.nasa.gov/Features/SmokeSecret/
- Voiland, A. Aerosols: Tiny Particles, Big Impact. Earth Observatory. http://earthobservatory.nasa.gov/Features/Aerosols/

Information about Satellite Data

- Aerosol Optical Depth. Earth Observatory. http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MODAL2_M_AER_OD
- Fire. Earth Observatory. http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD14A1_M_FIRE
- The Giovanni-NEO Instructional Cookbook. Giovanni. http://disc.sci.gsfc.nasa.gov/oceancolor/additional/science-focus/locus/index.shtml/Giovanni_NEO_cookbook_Introduction.shtml
- U.S. Air Quality: The Smog Blog University of Maryland Baltimore County. http://alg.umbc.edu/usaq/
- Understanding the Images. Smog Blog. http://alg.umbc.edu/usaq/archives/000693.html

General Student Learning Objectives

- Students will design, analyze, or carry out simple investigations and formulate appropriate conclusions based on data obtained or provided.
- Students will recognize and explain how human activities can accelerate or magnify many naturally occurring changes.
- The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.

Materials

- Digital camera (optional if you wish to continue the lab over multiple days)
- Data sheets (Appendix B)
- Thermometer (optional for multi-day monitoring)
- Computer with Google Earth and internet access to satellite data

Lessons

Engage

Students who live in urban areas have likely heard Air Quality Index reports on hot summer days. People become alarmed when the report is Code Red and everyone, not only sensitive groups, may begin to experience health effects. Students may remember hearing about the air quality issues in Beijing leading up to the Summer Olympics of 2008. The air in Beijing was hard to see through and posed a real risk to athletes' health.

Ask the students to read *A Cloud with a Silver Lining* and discuss it as a group. Does the United States have similar air quality issues today? What is the air quality in your community? Do you know the reading for today? Does it change over time? What causes it to get worse or better over time?

Recent extreme air quality events can be explored such as the Iceland volcano eruption of 2010 and fires in the western US. For information about current events in the United States, see Air Now (http://airnow.gov/) or The Smog Blog (http://alg.umbc.edu/usaq/)

Explore

Next have the students estimate their local air quality by measuring visibility. They may either take observations on a single day or they can use a camera and/or a weekly data sheet to observe the same location over a period of time. They will then compare their estimates of visibility with actual EPA data for ground-level air quality. They will be able to see if there is a relationship between what they observe and true measures of air pollution.

There are many ways to gauge air quality. The most common measure is visibility, since most of the constituents of air pollution form visible haze. You can use your own observations to estimate visibility wherever you are.

Estimate Visibility

Record current conditions:
Choose a location where you can make observations of the sky at about the same time every day. An ideal observation point will allow you to see landmarks at varying distances along the horizon to help you gauge visibility.

1. Record the date and time on your data sheet. If you are doing this lab in a single day, use the one-day data sheet. If you want to track air quality across a week, you should use the weekly data sheet.
2. Describe your location on your data page. Note factors that could influence your visibility. Are you on the 12th floor of a building? Are you in a valley, on a sports field surrounded by trees, or on tops of a small hill? Are you at ground level?

3. Observe or photograph the horizon. If you are doing this lab over multiple days, you will want to have students compare photographs from day to day, so make sure the photo is taken from the same location and perspective and as close to the same time as possible. Note the camera settings (ISO, exposure) to ensure that they are the same from day to day. [The user's manual for your camera should provide some guidance if you're not sure how to do this.]
4. Note the farthest landmark that you can see clearly when you look at the horizon.
5. Record the sky color. This is a subjective scale, and may vary slightly from student to student. The photo record should help students rank the color consistently over time.
    a. Dark blue
    b. Bright blue
    c. Light blue
    d. White/milky blue
    e. Brown/yellow
6. Record visibility. Again, this is a subjective scale.
    a. Extremely clear
    b. Clear
    c. Somewhat hazy
    d. Hazy
    e. Extremely hazy
7. Record the air temperature.
8. Note weather conditions, especially if they influence or impede your assessment of the sky color. Heavy rain, snow, or fog, for example, obscures the sky.
9. Since cloud cover can also impede visibility, you'll need to record how much of the sky is obscured by cloud. Looking directly overhead, estimate what percentage of the sky is covered with clouds. If you look at the horizon to assess cloud cover, your estimate will be high, since you can't see breaks in the clouds from an angle. Record both the percentage and the cloud cover category as follows:

    <10% Clear
    10–25% Isolated
    25–50% Scattered
    50–90% Broken Overcast
    >90 Overcast
    (from Cloud Protocols, pg 5, Globe Program.)

Calculate visibility with Google Earth:

1. Open Google Earth. If you don’t have the software on your computer, you can download it for free at http://earth.google.com/.
2. Type the address of your observation site in the “fly to” box on the upper left side of the page and hit enter. Google Earth will zoom into your location.

3. Place the cursor over your observation site. The latitude and longitude of that location will appear in the bar below the Earth. Note the latitude and longitude on your data sheet.
    a. To help you jump to your location for future observation, it will be helpful to put a placemark in this location. To place a placemark, click on the yellow pushpin in the top tool bar or go to the Add menu and select placemark.
    b. Click on the placemark on the map and drag it to your observation location. As you move the pin, the latitude and longitude of the pin's location will be displayed in the placemark pop-up screen. Make sure that the placemark is centered on the latitude and longitude you recorded as your location on the data sheet.
    c. Name the placemark so that you can save and return to the location next time you open Google Earth.
4. Locate the landmark you observed in step 1 on Google Earth. You may type the address or location in the "fly to" field as in step 2 or visually locate the landmark on the Google Earth display.
5. Zoom in or out until both the landmark and your observation point are visible on the screen at the same time.
6. Go to the Tools menu and select ruler. A Ruler tool box will open. Select line.
7. Click on your placemark (observation point).
8. Click on the landmark you observed on the horizon.
9. Google Earth will draw a straight line between the two points and tell you the length of the line. On the data sheet, record the distance between your observation point and the landmark. This will tell you approximately how far you saw that day.

You may repeat this procedure daily to track changes in your local air quality. You could also take several observations throughout the day to track how air quality changes throughout the day.

Relate visibility estimates with actual air quality data:
Poor air quality contributes to poor visibility, but poor visibility doesn't always mean that the air quality is bad. Fog or clouds may be limiting visibility. "The U.S. EPA, NOAA, NPS, tribal, state, and local agencies developed the AIRNow Web site to provide the public with easy access to national air quality information. The Web site offers daily AQI forecasts as well as real-time AQI conditions for over 300 cities across the US, and provides links to more detailed State and local air quality Web sites."

1. To find out if your measurements of visibility are related to air quality, go to AIRNow (http://AIRNow.gov). From the drop-down menu on the top of the page, select your state and click go. [Note: AIRNow provides air quality measurements for much of the United States, but measurements are not available for many regions. You will only be able to relate your observations of visibility to air

quality if AIRNow provides a measurement within 50 kilometers (30 miles) of your location.]

2. On the data sheet, note the air quality index for both ozone and particles as well as the color code.
3. How do the ozone and particulates readings compare to visibility observations in your area?

Explain

Ask the students to explore the National Park Service's web cam site that shows photos taken at national parks with corresponding particulate matter and ozone readings displayed with the photos. Ask the students to pick a park and find 3 photos of varying visibility and ask them to explain how what they see (or can't see, in this case) relates to the air pollution measurements. If visibility is low, what might be the source of the air pollution given the location of the national park? Open Google Earth to explore the areas upwind from the park and try to identify possible sources of air pollution. Are the sources from nature, such as a dust storm, or are they human-caused, such as a coal-fired power plant?

Extend

Next students will expand their understanding of air quality issues by taking a global look using satellite data. Because it takes time to process satellite images, this portion of the lab may have to be done the next day so that students can compare their observations to satellite observations from the same time. The students will need to read this background information so that they can interpret the satellite images:

Interpreting Satellite Images

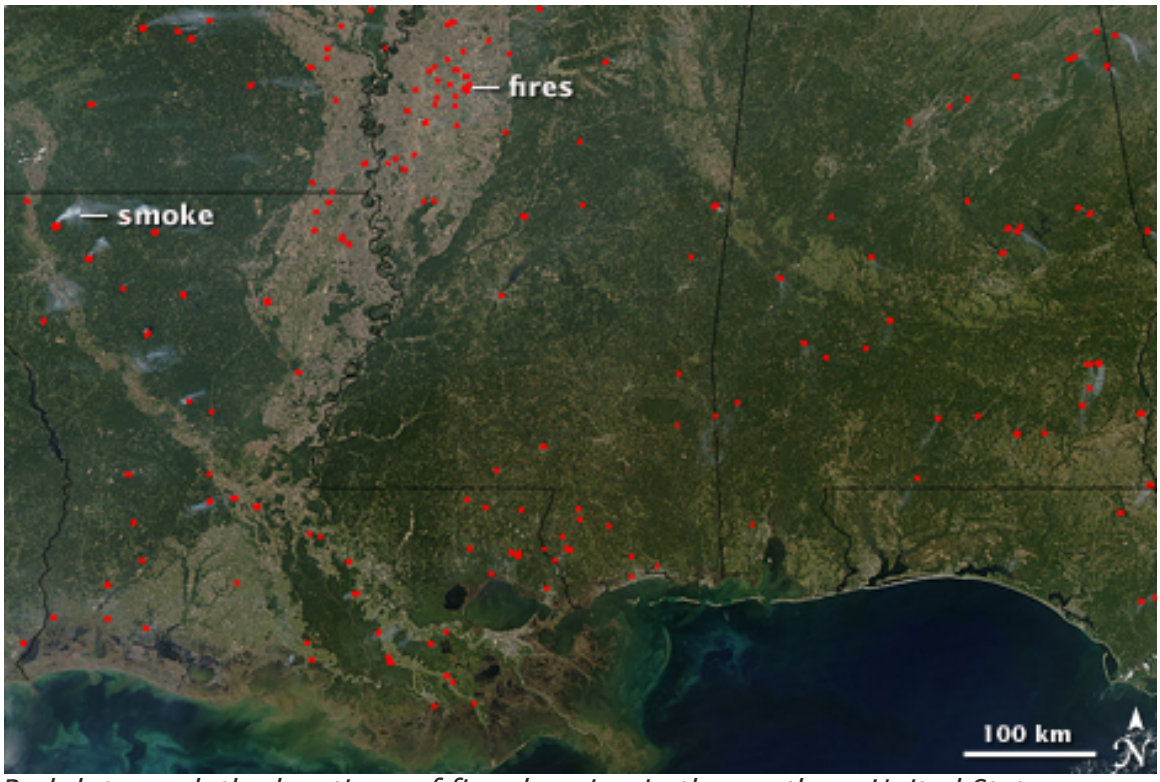
To improve air quality, it is important to know what contributes to polluting the air. Haze comes from a variety of sources. Your skies may be hazy from local traffic, or industry such as for example coal burning power plants, or the pollution may be coming in from somewhere else farther away. Satellite images help identify large areas of pollution caused by fires, dust or sand storms, volcanic eruptions, large industrial sources, or the transport of man-made pollution from other regions. Smaller sources, such as small industries or local roads won't be visible in satellite images.

Photo-like, true color images provide a very simple way to see if smoke, dust, or haze is being transported into your region. MODIS Rapid Response System provides true color images of much of the world. MODIS stands for the Moderate Resolution Imaging Spectroradiometer. It is an instrument that flies on two NASA satellites, Terra and Aqua. Both satellites orbit the Earth from pole to pole, so that each MODIS instrument sees the entire Earth every day. Terra MODIS passes overhead in the mid-morning local time, while Aqua captures images from the early afternoon. The MODIS Rapid Response System typically provides images within 4-6 hours after the satellite acquires them.

Haze is usually gray-white and very uniform in texture. Dust tends to be tan, though the color varies depending on the type of soil that is being picked up by the wind. Smoke ranges from brown to gray-white. It is not always possible to identify what kind of pollution you are seeing, since smoke haze and dust can look alike, but you can look for potential sources in the satellite image.

Smoke

MODIS records the location of fires on the ground by observing unusual hot spots. The instrument doesn't see every fire, but it will see large fires that may be contributing to air pollution. In these images, fires are represented with red dots.

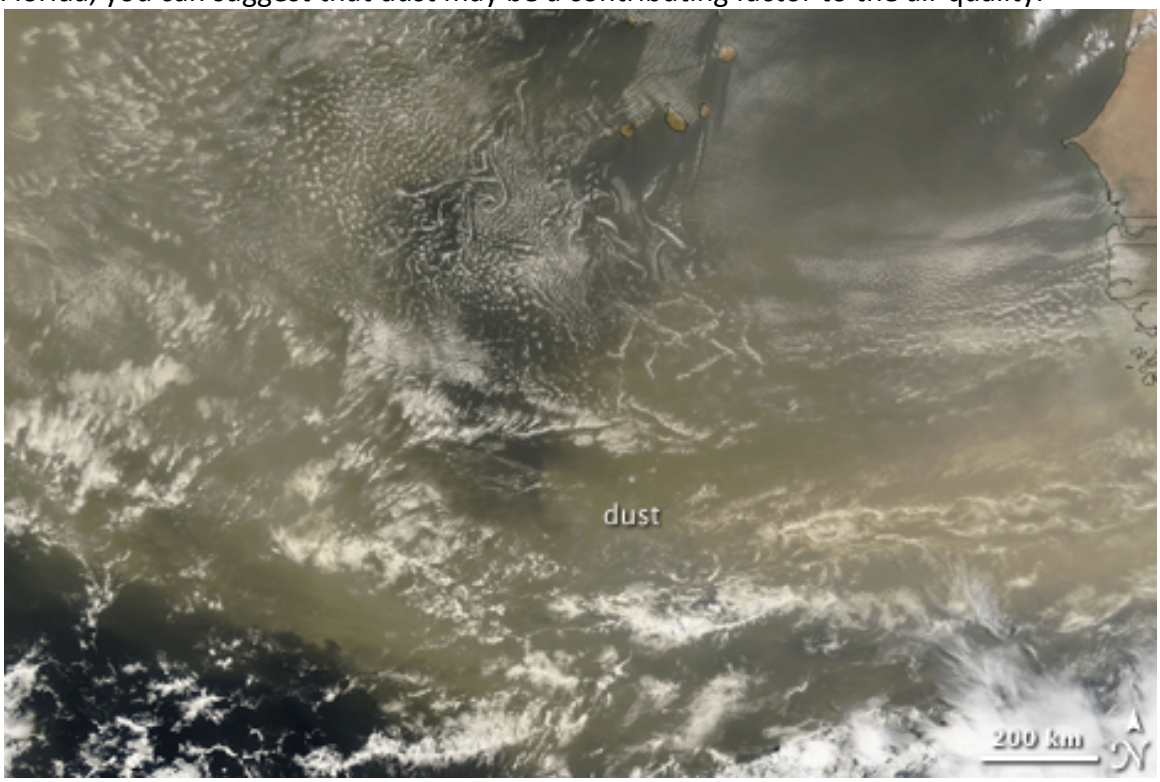


Red dots mark the locations of fires burning in the southern United States on October 15, 2005. Because there are several fires scattered across a wide region, they are likely agricultural fires, set to manage vegetation. Some of the fires produced white-gray plumes of smoke. Even though the fires are small, widespread burning can seriously impact regional air quality.

Dust

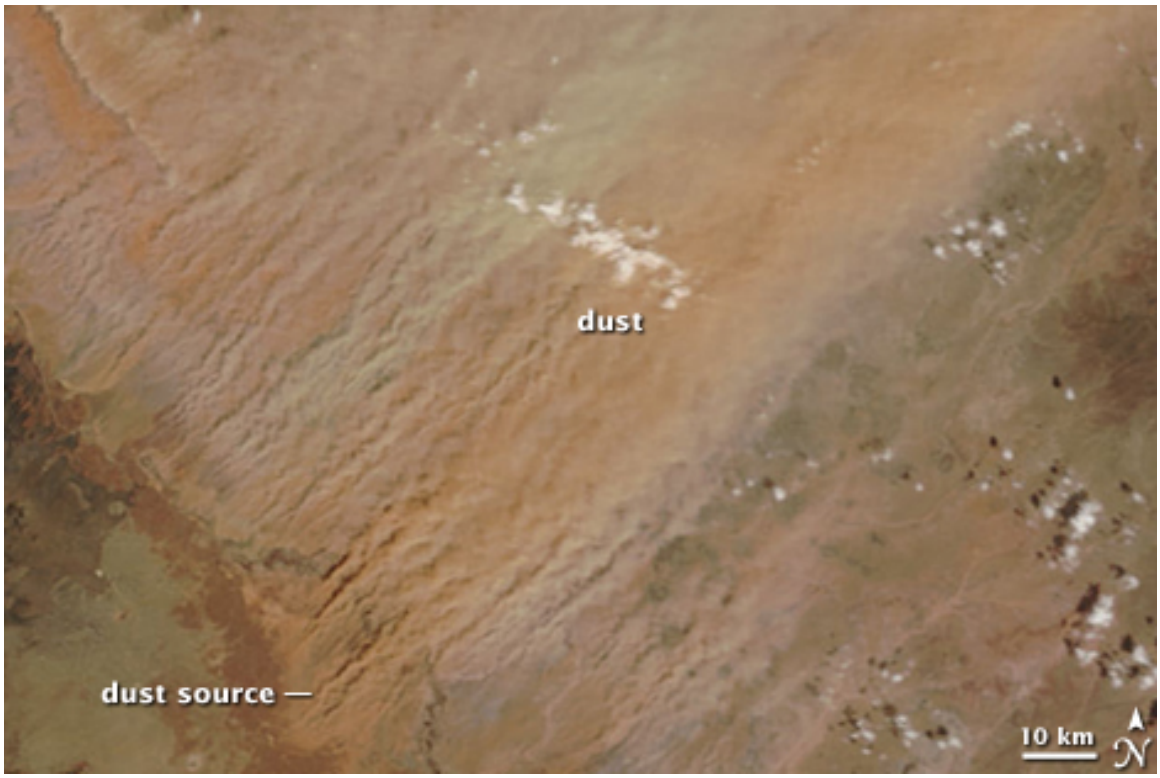
Not all dust storms are visible, but very large storms that last for several hours or days can be seen. The most common source of dust globally is the Sahara Desert. These giant storms sweep off West Africa and occasionally reach Florida and the Caribbean. By the time the dust reaches Florida, it is diffuse enough that it is difficult to see. If you live in Florida or the Caribbean, and you suspect that Saharan Dust may be clouding your skies,

click on the images of northwest Africa and look back through the previous week to see if dense plumes of dust are coming off the continent. If you see a storm moving towards Florida, you can suggest that dust may be a contributing factor to the air quality.



MODIS on NASA's Terra satellite captured the top image of dust blowing off the coast of West Africa on June 22, 2007. The storm lasted several days, crossing the Atlantic Ocean.

Other dust storms may have a local source. Often dust storms come from a small area of exposed soil. Click on 250m to see the most detail possible in the image and look at the point from which the plume is originating. You may be able to identify the source of the dust. Look for a compact plume rising from exposed land.



Dust sweeps northeast from distinct sources in central Arizona in this image from April 3, 2009. The dust plumes are tan and orange, depending on the type of soil that is being pulled into the air.

Haze

Haze from cars and power plants is gray-white in true color images. It is difficult to pin-point a single source, but you can see where the haze is.

A band of haze hung over the southeastern United States on August 5, 2002. The haze is gray compared to the bright white clouds to the north. Haze blurs the ground beneath it. Ground features are distinct where skies were clearer (lower right).

Find a satellite image of your area:

1. To access daily true color images of much of the world, go to the LANCE Rapid Response System: http://lance.nasa.gov/imagery/rapid-response/
2. Under "quick links" on the right side of the page, click on “subsets”: http://lance.nasa.gov/imagery/rapid-response/subsets/.
3. The page shows list of subset areas. Click on "North America" or your region. If your location is not listed, click on "other."
4. Click on the map over your location.
5. This will bring up the most recent images of the region. Click on previous to browse back to earlier days.
6. Click on the photo-like image (true color) on the left. A full-screen image will load.
7. Under vector options (above the image), select “fires + borders” from the drop-down menu and click "submit."
8. Click on 250m to get the most detailed image available
9. Click on "download a KMZ file for Google Earth.
10. Go to the downloaded file on your computer and open it. It should automatically open in Google Earth. If it does not, right click on the file and select "open with Google Earth."

11. Go to your location. (If you set up a placemarker earlier, you can double-click on it in the left menu under "Places," and Google Earth will take you to your location.
12. What are the conditions at your location? Do you see dust, haze, clouds, or clear ground? Record your observations in the data sheet.
13. If you see haze, dust, or smoke, can you identify a point source? Is pollution entering your area from somewhere else?

Overlay air quality data on Google Earth:

Satellite images are helpful in seeing long-range transport of pollutants from other regions, but they don't tell you what pollution levels were on the ground. They see pollutants in the entire atmosphere, so the pollutants you see in the satellite image could be kilometers above the ground. To find out if the pollution you are seeing in the satellite image is on the ground, that is nearest to the surface you need to compare ground measurements to the satellite measurements.

1. To get ground measurements, go to AIRNow: http://airnow.gov.
2. Click on the AIRNow map, and then, under Resources in the right menu, select, AQI in Google Earth: http://cfpub.epa.gov/airnow/index.cfm?action=google_earth.index
3. Follow the directions on the page to download the Air Quality Index into Google Earth. The file should open on top of the MODIS image.
4. The data points that are exported are current measurements. Click on the circle nearest your observation location and note the time and date the data were updated. (Note: there may not be an AIRNow dot close to your area. If that is the case, look for a dot that is within 100 km and use the measurements for that location.) Does the date correspond to the date the satellite image was taken?
5. Record your observations about how the EPA ground measurements match the satellite image. If so, you can attribute at least some of the pollution to the source identified in the satellite image.

Extension Discussions:

To further students' interest and understanding of air quality, start discussions or ask students to investigate and report on these questions:

1. How does air quality affect regional, national, and global economies? For example, how did the United States Dust Bowl of the 1930s affect the national economy?
2. How does air quality in the United States compare to that of other countries? Can you identify other countries with better air quality? Others that have worse air quality? What attributes to those differences (e.g., weather patterns, population, etc.)? Are air pollution standards different in those countries? In your opinion, what country has the best air quality standards for regulating air pollution?

3. When you look at areas around the world with the worst air quality, how does that relate to the economic status of the people who live in those areas? Are poor people more likely to be exposed to industrial air pollution?

Evaluate

Evaluation of student comprehension is an ongoing process throughout the learning activities. Here are a few ideas for creating distinct evaluation activities:

1. Print out a new Google Earth image with air quality index readings and satellite images superimposed. Ask the students to explain what they see.
2. Have students provide a daily weather announcement to the school that includes a local air quality index reading. Have them alert other students and teachers to any unusual readings or predictions based on events affecting their region.

Advanced Extensions

These extension activities may be done with advanced students or on additional days. They may also provide ideas for independent research projects, such as a science fair project.

Measuring Visibility

Human observations of haziness are subjective, but you can make a numerical measurement of the amount of light reaching the ground using a sun photometer. Scientists relate these measurements to particle pollution in the atmosphere. A sun photometer ranges in price from $75 to $130, and may be purchased through the GLOBE Program at http://www.globe.gov/fsl/html/templ.cgi?soil_sun.

GLOBE, Global Learning and Observations to Benefit the Environment (http://www.globe.gov/), is a world-wide program in which students and teachers collect environmental data that is useful to scientists who study Earth's environment. The GLOBE Program developed a procedure for measuring aerosols using a sun photometer, which is available at http://www.globe.gov/tctg/aerosol.pdf?sectionId=9&rg=n&lang=EN.

Measuring Ozone and Particle Pollution

While visibility is a good gauge for air quality, you may not be able to see all pollutants. Using simple test strips, you can measure ground-level ozone, a major component of air pollution.

To measure ozone, you will need an ozone test kit. A relatively inexpensive test kit and reader may be purchased through Vistanomics: http://ecobadge.com/Merchant5/merchant.mvc?Screen=CTGY&Store_Code=ecobadge&Category_Code=researchers.

The Ecobadge kit contains test strips that change color when exposed to ozone. The card records the peak ozone exposure, which can be estimated from the card's color. A

set of cards and a color chart may be purchased for $39.99 (see Eco Badge Kit, Jr: http://www.ecobadge.com/Merchant5/merchant.mvc?Screen=PROD&Store_Code=ecobadge&Product_Code=EBKJR). You may purchase a reader for $189.99 to get a more precise numeric measurement of the ozone level. See Zikua the Eco Badge Test Card Reader: http://www.ecobadge.com/Merchant5/merchant.mvc?Screen=PROD&Store_Code=ecobadge&Product_Code=EBTCR.

The GLOBE Program developed a protocol for measuring ground-level ozone using the cards and a card reader. It is available at http://www.globe.gov/tctg/ozone.pdf?sectionId=15&rg=n&lang=EN.

Measuring Pollution from Space

Satellites measure the concentration of particles (aerosols) in the atmosphere by observing how much light reaches the surface of the Earth and how much is reflected off the aerosols. The measurement is called aerosol optical depth or aerosol optical thickness. It is the same measurement that may have made from the ground using a sun photometer. Using the following procedures, you can compare the satellite measurement of aerosol optical depth to the ground measurement from the sun photometer. You can also compare the satellite measurements with visibility or ozone concentrations to see the correlation.

NASA Earth Observations (NEO) was designed to provide easy access to global satellite images for teachers, students, museums and other public organizations, and citizen scientists. The system generates images based on data from various satellite instruments. For aerosol optical depth, a color is assigned to a range of aerosol optical depth values. NEO's analysis tool allows you to click on the image to get the data value assigned to the color at the point you selected.

1. To measure aerosol optical depth using NEO, go to http://neo.sci.gsfc.nasa.gov/Search.html
2. Click on the atmosphere tab under the map
3. Select "aerosol optical thickness (MODIS)" from the drop-down menu. Aerosol optical thickness is the same measurement as aerosol optical depth.
4. The most recent month will load on the screen. To compare the data to the daily values that you are tracking, you will want a daily image.
5. Under "matching data sets" on the right side of the screen, select Aerosol Optical Thickness (1 day Terra MODIS or 1 day Aqua MODIS). If you made your measurement in the morning, choose Terra. If you made your ground measurements in the afternoon, choose Aqua.
6. The most recent daily data will load. If you want to see a different date, scroll down the page and select another date from the list of search result. The previous and next buttons at the end of the list allow you to scroll backwards and forwards to see additional dates.

7. Under search results, identify the date you are interested in. Click on Analyze this image under the date. This will put the data in the "analysis" shopping cart on the right side of the page. You can select up to three dates to analyze at once.
8. Click "configure/launch analysis" under the analysis tab on the right.
9. Click on the "select area" tab.
10. Enter the latitude and longitude of your observation location. You will need to identify a small box around your area of interest. You can also click on the map and draw a box, but this method is less precise and harder to duplicate from day to day. (NOTE: you can get the latitude and longitude from Google Earth. Open Google Earth and zoom down to your location. Click on the location and the latitude and longitude should appear on the bottom of the screen.)
11. Click select.
12. Click "launch analysis" at the bottom of the select area box.
13. Select Probe
14. Move the cursor over the screen until you find your latitude and longitude. Record the aerosol optical depth value for that location.
15. Over time you can compare your ground measurements, the EPA air quality index for ozone and particles, and the satellite measurement of aerosol optical depth. You can also do these long-range comparisons using GIOVANNI.

Using GIOVANNI to analyze satellite data

Another powerful tool for accessing, visualizing, and analyzing NASA satellite data is Giovanni. While NEO was designed to provide easy public access to global data sets, Giovanni was designed to provide scientists and students an easy way to visualize and analyze satellite data without actually downloading the full data files. As such, Giovanni provides data and analysis tools not available in NEO.

Using NEO, you charted the aerosol optical depth for your observation location. With Giovanni, you can correlate aerosol optical depth measurements for your region with EPA ground measurements of particles to find out if the aerosols the satellite measured were high in the atmosphere or close to the ground where they affect the air we breathe. You can also use data from another satellite, CALIPSO, to find out where aerosols are in the atmosphere.

To compare satellite observations with ground measurements of aerosols:

1. Open the Giovanni web page: http://disc.sci.gsfc.nasa.gov/giovanni
2. From the table in the middle of the page, click on Aerosol Daily.
3. Zoom in to your area of interest on the map, then draw a box around your region. The size of the box will depend on what your interests are. If you want to see how air quality on the ground compares to satellite observations for your state, you might draw a box around your state. The larger your box is, the more likely it is that you will have enough data points to see a meaningful trend.

4. The latitude and longitude coordinates for your selected region will appear beneath the map. On the data sheet, note the bounding coordinates of your box so that you can duplicate the procedure from day to day.
5. Under measurement, click in the box next to “aerosol optical depth at 550 nm” under Terra MODIS or Aqua MODIS. Terra MODIS collects measurements in the late morning, while Aqua MODIS flies overhead in the early afternoon. Select the satellite that most closely matches your observation time in Part 1.
6. Under measurement, click on the box next to Fine Particulate Matter – PM2.5.
7. Scroll to the bottom of the page, and enter the date range you want to analyze. In the example shown here, a single day (July 26, 2005) will be analyzed, so the begin and end date are both set to July 26, 2005. You may choose to analyze a longer period of time.
8. [screen shot]
9. Under visualization, select lat-lon map.
10. Click Generate visualization. Giovanni will generate two images, one for the satellite aerosol optical depth and one for the EPA PM2.5 measurements. On July 26, 2005, the two measurements reveal similar patterns.

Plot the Relationship between ground measurements and satellite data:

Satellites record the sum of all the particles they see in a column of the atmosphere stretching from their position to the ground. Only a portion of the pollution that satellites measure is actually in the air near the ground, where air quality monitors are. How much of what you see in the satellite data is pollution that you are breathing on the ground? To explore the relationship between the EPA ground measurements of particles and the satellite measurement of particles, you can generate a scatter plot.

1. Open the Giovanni web page: http://disc.sci.gsfc.nasa.gov/giovanni
2. From the table in the middle of the page, click on Aerosol Daily.
3. If you compared satellite data and EPA PM2.5 measurements in the previous section, enter the latitude and longitude coordinates of your box. Otherwise, zoom in to your area of interest on the map, then draw a box around your region. The size of the box will depend on what your interests are. If you want to see how air quality on the ground compares to satellite observations for your state, you might draw a box around your state. The larger your box is, the more likely it is that you will have enough data points to see a meaningful trend.
4. The latitude and longitude coordinates for your selected region will appear beneath the map. On the data sheet, note the bounding coordinates of your box so that you can duplicate the procedure from day to day.
5. Under measurement, click in the box next to “aerosol optical depth at 550 nm” under Terra MODIS or Aqua MODIS. Terra MODIS collects measurements in the late morning, while Aqua MODIS flies overhead in the

early afternoon. Select the satellite that most closely matches your observation time in Part 1.

6. Under measurement, click on the box next to Fine Particulate Matter – PM2.5.
7. Scroll to the bottom of the page, and enter the date range you want to analyze. You should choose a period of at least two weeks to get enough data points to see any sort of relationship between the satellite and ground data. This example uses the month of July 2005.
8. Under visualization, select Scatter plot and click Generate plot
9. When the plot loads, scroll to the bottom of the page to "plot preferences" and select "yes" for line fitting.
10. The r-value is a measurement of correlation between the two values. The closer the r-value is to 1, the greater the correlation between the values. When the aerosol optical depth correlates with the ground measurements, it means that the aerosols that the satellite observed were close to the ground. When the two measurements are not correlated, the aerosols the satellite observed were high in the atmosphere or clouds or a bright surface (sunglint off the ocean, a desert or snow) prevented the satellite from seeing aerosols close to the ground.

For additional ideas for analyzing air quality using satellite data, please see Pollution in the United States and China on the Giovanni web site: http://disc.sci.gsfc.nasa.gov/oceancolor/locus/air_pollution.shtml#aod.

Appendix A: A Cloud with a Silver Lining

Appendix B: Air Quality Data Sheets

Appendix C: Student Instructions